Measurements of branching fractions, polarizations, and direct CP-violation asymmetries in B+→ 0K*+ and B+→f0(980)K*+ decays

BABAR Collaboration ; del Amo Sanchez, P ; Snoek, H L

Abstract: We present measurements of the branching fractions, longitudinal polarization, and direct CP-violation asymmetries for the decays B+→ 0K*+ and B+→f0(980)K*+ with a sample of (467±5)×106BB pairs collected with the BABAR detector at the PEP-II asymmetric-energy e+e- collider at the SLAC National Accelerator Laboratory. We observe B+→ 0K*+ with a significance of 5.3 and measure the branching fraction B(B+→ 0K*+)=(4.6±1.0±0.4)×10-6, the longitudinal polarization fL=0.78±0.12±0.03, and the CP-violation asymmetry ACP=0.31±0.13±0.03. We observe B+→f0(980)K*+ and measure the branching fraction B(B+→f0(980)K*+)×B(f0(980)→ + -)=(4.2±0.6±0.3)×10-6 and the CP-violation asymmetry ACP=-0.15±0.12±0.03. The first uncertainty quoted is statistical and the second is systematic.

DOI: https://doi.org/10.1103/PhysRevD.83.051101

Other titles: Measurements of branching fractions, polarizations, and direct CP-violation asymmetries in B –> rho K* and B –> f0(980) K* decays

Originally published at:
BABAR Collaboration; del Amo Sanchez, P; Snoek, H L (2011). Measurements of branching fractions, polarizations, and direct CP-violation asymmetries in B+→ 0K*+ and B+→f0(980)K*+ decays. Physical Review D, 83(5):051101.
DOI: https://doi.org/10.1103/PhysRevD.83.051101

BABAR-PUB-06/050
SLAC-PUB-11997

Measurements of branching fractions, polarizations, and direct CP-violation asymmetries in $B \to \rho K^*$ and $B \to f_0(980) K^*$ decays

B. Aubert,[1] R. Barate,[1] M. Bona,[1] D. Boutigny,[1] F. Couderc,[1] Y. Karyotakis,[1] J. P. Lees,[1] V. Poireau,[1] V. Tisserand,[1] A. Zghiche,[1] E. Grauges,[2] A. Palano,[3] J. C. Chen,[4] N. D. Qi,[4] G. Rong,[4] P. Wang,[4] Y. S. Zhu,[4] G. Eigen,[5] I. Ofte,[5] B. Stugu,[5] G. S. Abrams,[6] M. Battaglia,[6] D. N. Brown,[6] J. Button-Shafer,[6] R. N. Cahn,[6] E. Charles,[6] M. S. Gill,[6] Y. Groysman,[6] R. G. Jacobsen,[6] J. A. Kadyk,[6] L. T. Kerth,[6] Yu. G. Kolomensky,[6] G. Kukartsev,[6] G. Lynch,[6] L. M. Mir,[6] T. J. Orimoto,[6] M. Pripstein,[6] N. A. Roe,[6] M. T. Ronan,[6] W. A. Wenzel,[6] P. del Amo Sanchez,[7] M. Barrett,[7] K. E. Ford,[7] T. J. Harrison,[7] A. J. Hart,[7] C. M. Hawkes,[7] S. E. Morgan,[7] A. T. Watson,[7] T. Held,[8] H. Koch,[8] B. Lewandowski,[8] M. Pelizaeus,[8] K. Peters,[8] T. Schroeder,[8] M. Steinke,[8] J. T. Boyd,[9] J. P. Burke,[9] W. N. Cottingham,[9] D. Walker,[9] T. Cuhadar-Donszelmann,[10] B. G. Fulsom,[10] C. Hearty,[10] N. S. Knecht,[10] T. S. Mattison,[10] J. A. McKenna,[10] A. Khan,[11] P. Kyberd,[11] M. Saleem,[11] D. J. Sherwood,[11] L. Teodorescu,[11] V. E. Blinov,[12] A. D. Bukin,[12] V. P. Druzhinin,[12] V. B. Golubev,[12] A. P. Onuchin,[12] S. I. Serednyakov,[12] Yu. I. Skovpen,[12] E. P. Solodov,[12] K. Yu Todyshev,[12] D. S. Best,[13] M. Bondioli,[13] M. Bruinsma,[13] M. Chao,[13] S. Curry,[13] I. Eschrich,[13] D. Kirkby,[13] A. J. Lankford,[13] P. Lund,[13] M. Mandelkern,[13] R. K. Mommsen,[13] W. Roethel,[13] D. P. Stoker,[13] S. Abachi,[14] C. Buchanan,[14] S. D. Foulkes,[15] J. W. Gary,[15] O. Long,[15] B. C. Shen,[15] K. Wang,[15] L. Zhang,[15] H. K. Hadavand,[16] E. J. Hill,[16] H. P. Paar,[16] S. Rahatlou,[16] V. Sharma,[16] J. W. Berryhill,[17] C. Campagnari,[17] A. Cunha,[17] B. Dahmes,[17] T. M. Hong,[17] D. Kovalskyi,[17] J. D. Richman,[17] T. W. Beck,[18] A. M. Eisner,[18] C. J. Flacco,[18] C. A. Heusch,[18] J. Kroseberg,[18] W. S. Lockman,[18] G. Nesom,[18] T. Schalk,[18] B. A. Schumm,[18] A. Seiden,[18] P. Spradlin,[18] D. C. Williams,[18] M. G. Wilson,[18] J. Albert,[19] E. Chen,[19] A. Dvoretskii,[19] F. Fang,[19] D. G. Hitlin,[19] I. Narsky,[19] T. Piatenko,[19] F. C. Porter,[19] A. Ryd,[19] A. Samuel,[19] G. Mancinelli,[20] B. T. Meadows,[20] K. Mishra,[20] M. D. Sokoloff,[20] F. Blanc,[21] P. C. Bloom,[21] S. Chen,[21] W. T. Ford,[21] J. F. Hirschauer,[21] A. Kreisel,[21] M. Nagel,[21] U. Nauenberg,[21] A. Olivas,[21] W. O. Ruddick,[21] J. G. Smith,[21] K. A. Ulmer,[21] S. R. Wagner,[21] J. Zhang,[21] A. Chen,[22] E. A. Eckhart,[22] A. Soffer,[22] W. H. Toki,[22] R. J. Wilson,[22] F. Winklmeier,[22] Q. Zeng,[22] D. D. Altenburg,[23] E. Feltresi,[23] A. Hauke,[23] H. Jasper,[23] A. Petzold,[23] B. Spaan,[23] T. Brandt,[24] V. Klose,[24] H. M. Lacker,[24] W. F. Mader,[24] R. Nogowski,[24] J. Schubert,[24] K. R. Schubert,[24] R. Schwierz,[24] J. E. Sundermann,[24] A. Volk,[24] D. Bernard,[25] G. R. Bonneaud,[25] P. Grenier,[25,*] E. Latour,[25] Ch. Thiebaux,[25] M. Verderi,[25] P. J. Clark,[26] W. Gradl,[26] F. Muheim,[26] S. Playfer,[26] A. I. Robertson,[26] Y. Xie,[26] M. Andreotti,[27] D. Bettoni,[27] C. Bozzi,[27] R. Calabrese,[27] G. Cibinetto,[27] E. Luppi,[27] M. Negrini,[27] A. Petrella,[27] L. Piemontese,[27] E. Prencipe,[27] F. Anulli,[28] R. Baldini-Ferroli,[28] A. Calcaterra,[28] R. de Sangro,[28] G. Finocchiaro,[28] S. Pacetti,[28] P. Patteri,[28] I. M. Peruzzi,[28,†] M. Piccolo,[28] M. Rama,[28] A. Zallo,[28] A. Buzzo,[29] R. Capra,[29] R. Contri,[29] M. Lo Vetere,[29] M. M. Macri,[29] M. R. Monge,[29] S. Passaggio,[29] C. Patrignani,[29] E. Robutti,[29] A. Santroni,[29] S. Tosi,[29] G. Brandenburg,[30] K. S. Chaisanguanthum,[30] M. Morii,[30] J. Wu,[30] R. S. Dubitzky,[31] J. Marks,[31] S. Schenk,[31] U. Uwer,[31] D. J. Bard,[32] W. Bhimji,[32] D. A. Bowerman,[32] P. D. Dauncey,[32] U. Egede,[32] R. L. Flack,[32] J. A. Nash,[32] M. B. Nikolich,[32] W. Panduro Vazquez,[32] P. K. Behera,[33] X. Chai,[33] M. J. Charles,[33] U. Mallik,[33] N. T. Meyer,[33] V. Ziegler,[33] J. Cochran,[34] H. B. Crawley,[34] L. Dong,[34] V. Eyges,[34] W. T. Meyer,[34] S. Prell,[34] E. I. Rosenberg,[34] A. E. Rubin,[34] A. V. Gritsan,[35] A. G. Denig,[36] M. Fritsch,[36] G. Schott,[36] N. Arnaud,[37] M. Davier,[37] G. Grosdidier,[37] A. Höcker,[37] F. Le Diberder,[37] V. Lepeltier,[37] A. M. Lutz,[37] A. Oyanguren,[37] S. Pruvot,[37] S. Rodier,[37] P. Roudeau,[37] M. H. Schune,[37] A. Stocchi,[37] W. F. Wang,[37] G. Wormser,[37] C. H. Cheng,[38] D. J. Lange,[38] D. M. Wright,[38] C. A. Chavez,[39] I. J. Forster,[39] J. R. Fry,[39] E. Gabathuler,[39] R. Gamet,[39] K. A. George,[39] D. E. Hutchcroft,[39] D. J. Payne,[39] K. C. Schofield,[39] C. Touramanis,[39] A. J. Bevan,[40] F. Di Lodovico,[40] W. Menges,[40] R. Sacco,[40] G. Cowan,[41] H. U. Flaecher,[41] D. A. Hopkins,[41] P. S. Jackson,[41] T. R. McMahon,[41] S. Ricciardi,[41] F. Salvatore,[41] A. C. Wren,[41] D. N. Brown,[42] C. L. Davis,[42] J. Allison,[43] N. R. Barlow,[43] R. J. Barlow,[43] Y. M. Chia,[43] C. L. Edgar,[43] G. D. Lafferty,[43] M. T. Naisbit,[43] J. C. Williams,[43] J. I. Yi,[43] C. Chen,[44] W. D. Hulsbergen,[44] A. Jawahery,[44] C. K. Lae,[44] D. A. Roberts,[44] G. Simi,[44] G. Blaylock,[45] C. Dallapiccola,[45] S. S. Hertzbach,[45] X. Li,[45] T. B. Moore,[45] S. Saremi,[45] H. Staengle,[45] R. Cowan,[46] G. Sciolla,[46] S. J. Sekula,[46] M. Spitznagel,[46] F. Taylor,[46] R. K. Yamamoto,[46] H. Kim,[47]

S. E. Mclachlin,[47] P. M. Patel,[47] S. H. Robertson,[47] A. Lazzaro,[48] V. Lombardo,[48] F. Palombo,[48] J. M. Bauer,[49] L. Cremaldi,[49] V. Eschenburg,[49] R. Godang,[49] R. Kroeger,[49] D. A. Sanders,[49] D. J. Summers,[49] H. W. Zhao,[49] S. Brunet,[50] D. Côté,[50] M. Simard,[50] P. Taras,[50] F. B. Viaud,[50] H. Nicholson,[51] N. Cavallo,[52, ‡] G. De Nardo,[52] F. Fabozzi,[52, ‡] C. Gatto,[52] L. Lista,[52] D. Monorchio,[52] P. Paolucci,[52] D. Piccolo,[52] C. Sciacca,[52] M. Baak,[53] G. Raven,[53] H. L. Snoek,[53] C. P. Jessop,[54] J. M. LoSecco,[54] T. Allmendinger,[55] G. Benelli,[55] K. K. Gan,[55] K. Honscheid,[55] D. Hufnagel,[55] P. D. Jackson,[55] H. Kagan,[55] R. Kass,[55] A. M. Rahimi,[55] R. Ter-Antonyan,[55] Q. K. Wong,[55] N. L. Blount,[56] J. Brau,[56] R. Frey,[56] O. Igonkina,[56] M. Lu,[56] R. Rahmat,[56] N. B. Sinev,[56] D. Strom,[56] J. Strube,[56] E. Torrence,[56] A. Gaz,[57] M. Margoni,[57] M. Morandin,[57] A. Pompili,[57] M. Posocco,[57] M. Rotondo,[57] F. Simonetto,[57] R. Stroili,[57] C. Voci,[57] M. Benayoun,[58] J. Chauveau,[58] H. Briand,[58] P. David,[58] L. Del Buono,[58] Ch. de la Vaissière,[58] O. Hamon,[58] B. L. Hartfiel,[58] M. J. J. John,[58] Ph. Leruste,[58] J. Malclès,[58] J. Ocariz,[58] L. Roos,[58] G. Therin,[58] L. Gladney,[59] J. Panetta,[59] M. Biasini,[60] R. Covarelli,[60] C. Angelini,[61] G. Batignani,[61] S. Bettarini,[61] F. Bucci,[61] G. Calderini,[61] M. Carpinelli,[61] R. Cenci,[61] F. Forti,[61] M. A. Giorgi,[61] A. Lusiani,[61] G. Marchiori,[61] M. A. Mazur,[61] M. Morganti,[61] N. Neri,[61] E. Paoloni,[61] G. Rizzo,[61] J. J. Walsh,[61] M. Haire,[62] D. Judd,[62] D. E. Wagoner,[62] J. Biesiada,[63] N. Danielson,[63] P. Elmer,[63] Y. P. Lau,[63] C. Lu,[63] J. Olsen,[63] A. J. S. Smith,[63] A. V. Telnov,[63] F. Bellini,[64] G. Cavoto,[64] A. D'Orazio,[64] D. del Re,[64] E. Di Marco,[64] R. Faccini,[64] F. Ferrarotto,[64] F. Ferroni,[64] M. Gaspero,[64] L. Li Gioi,[64] M. A. Mazzoni,[64] S. Morganti,[64] G. Piredda,[64] F. Polci,[64] F. Safai Tehrani,[64] C. Voena,[64] M. Ebert,[65] H. Schröder,[65] R. Waldi,[65] T. Adye,[66] N. De Groot,[66] B. Franek,[66] E. O. Olaiya,[66] F. F. Wilson,[66] R. Aleksan,[67] S. Emery,[67] M. Escalier,[67] A. Gaidot,[67] S. F. Ganzhur,[67] G. Hamel de Monchenault,[67] W. Kozanecki,[67] M. Legendre,[67] G. Vasseur,[67] Ch. Yèche,[67] M. Zito,[67] X. R. Chen,[68] H. Liu,[68] W. Park,[68] M. V. Purohit,[68] J. R. Wilson,[68] M. T. Allen,[69] D. Aston,[69] R. Bartoldus,[69] P. Bechtle,[69] N. Berger,[69] R. Claus,[69] J. P. Coleman,[69] M. R. Convery,[69] M. Cristinziani,[69] J. C. Dingfelder,[69] J. Dorfan,[69] G. P. Dubois-Felsmann,[69] D. Dujmic,[69] W. Dunwoodie,[69] R. C. Field,[69] T. Glanzman,[69] S. J. Gowdy,[69] M. T. Graham,[69] V. Halyo,[69] C. Hast,[69] T. Hryn'ova,[69] W. R. Innes,[69] M. H. Kelsey,[69] P. Kim,[69] D. W. G. S. Leith,[69] S. Li,[69] S. Luitz,[69] V. Luth,[69] H. L. Lynch,[69] D. B. MacFarlane,[69] H. Marsiske,[69] R. Messner,[69] D. R. Muller,[69] C. P. O'Grady,[69] V. E. Ozcan,[69] A. Perazzo,[69] M. Perl,[69] T. Pulliam,[69] B. N. Ratcliff,[69] A. Roodman,[69] A. A. Salnikov,[69] R. H. Schindler,[69] J. Schwiening,[69] A. Snyder,[69] J. Stelzer,[69] D. Su,[69] M. K. Sullivan,[69] K. Suzuki,[69] S. K. Swain,[69] J. M. Thompson,[69] J. Va'vra,[69] N. van Bakel,[69] M. Weaver,[69] A. J. R. Weinstein,[69] W. J. Wisniewski,[69] M. Wittgen,[69] D. H. Wright,[69] A. K. Yarritu,[69] K. Yi,[69] C. C. Young,[69] P. R. Burchat,[70] A. J. Edwards,[70] S. A. Majewski,[70] B. A. Petersen,[70] C. Roat,[70] L. Wilden,[70] S. Ahmed,[71] M. S. Alam,[71] R. Bula,[71] J. A. Ernst,[71] V. Jain,[71] B. Pan,[71] M. A. Saeed,[71] F. R. Wappler,[71] S. B. Zain,[71] W. Bugg,[72] M. Krishnamurthy,[72] S. M. Spanier,[72] R. Eckmann,[73] J. L. Ritchie,[73] A. Satpathy,[73] C. J. Schilling,[73] R. F. Schwitters,[73] J. M. Izen,[74] X. C. Lou,[74] S. Ye,[74] F. Bianchi,[75] F. Gallo,[75] D. Gamba,[75] M. Bomben,[76] L. Bosisio,[76] C. Cartaro,[76] F. Cossutti,[76] G. Della Ricca,[76] S. Dittongo,[76] L. Lanceri,[76] L. Vitale,[76] V. Azzolini,[77] F. Martinez-Vidal,[77] Sw. Banerjee,[78] B. Bhuyan,[78] C. M. Brown,[78] D. Fortin,[78] K. Hamano,[78] R. Kowalewski,[78] I. M. Nugent,[78] J. M. Roney,[78] R. J. Sobie,[78] J. J. Back,[79] P. F. Harrison,[79] T. E. Latham,[79] G. B. Mohanty,[79] M. Pappagallo,[79] H. R. Band,[80] X. Chen,[80] B. Cheng,[80] S. Dasu,[80] M. Datta,[80] K. T. Flood,[80] J. J. Hollar,[80] P. E. Kutter,[80] B. Mellado,[80] A. Mihalyi,[80] Y. Pan,[80] M. Pierini,[80] R. Prepost,[80] S. L. Wu,[80] Z. Yu,[80] and H. Neal[81]

(The *BABAR* Collaboration)

[1]*Laboratoire de Physique des Particules, F-74941 Annecy-le-Vieux, France*
[2]*Universitat de Barcelona, Facultat de Fisica Dept. ECM, E-08028 Barcelona, Spain*
[3]*Università di Bari, Dipartimento di Fisica and INFN, I-70126 Bari, Italy*
[4]*Institute of High Energy Physics, Beijing 100039, China*
[5]*University of Bergen, Institute of Physics, N-5007 Bergen, Norway*
[6]*Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA*
[7]*University of Birmingham, Birmingham, B15 2TT, United Kingdom*
[8]*Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany*
[9]*University of Bristol, Bristol BS8 1TL, United Kingdom*
[10]*University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1*
[11]*Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom*
[12]*Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia*
[13]*University of California at Irvine, Irvine, California 92697, USA*
[14]*University of California at Los Angeles, Los Angeles, California 90024, USA*
[15]*University of California at Riverside, Riverside, California 92521, USA*
[16]*University of California at San Diego, La Jolla, California 92093, USA*

[17]University of California at Santa Barbara, Santa Barbara, California 93106, USA
[18]University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA
[19]California Institute of Technology, Pasadena, California 91125, USA
[20]University of Cincinnati, Cincinnati, Ohio 45221, USA
[21]University of Colorado, Boulder, Colorado 80309, USA
[22]Colorado State University, Fort Collins, Colorado 80523, USA
[23]Universität Dortmund, Institut für Physik, D-44221 Dortmund, Germany
[24]Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany
[25]Ecole Polytechnique, Laboratoire Leprince-Ringuet, F-91128 Palaiseau, France
[26]University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom
[27]Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy
[28]Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy
[29]Università di Genova, Dipartimento di Fisica and INFN, I-16146 Genova, Italy
[30]Harvard University, Cambridge, Massachusetts 02138, USA
[31]Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany
[32]Imperial College London, London, SW7 2AZ, United Kingdom
[33]University of Iowa, Iowa City, Iowa 52242, USA
[34]Iowa State University, Ames, Iowa 50011-3160, USA
[35]Johns Hopkins University, Baltimore, Maryland 21218, USA
[36]Universität Karlsruhe, Institut für Experimentelle Kernphysik, D-76021 Karlsruhe, Germany
[37]Laboratoire de l'Accélérateur Linéaire, IN2P3-CNRS et Université Paris-Sud 11,
Centre Scientifique d'Orsay, B.P. 34, F-91898 ORSAY Cedex, France
[38]Lawrence Livermore National Laboratory, Livermore, California 94550, USA
[39]University of Liverpool, Liverpool L69 7ZE, United Kingdom
[40]Queen Mary, University of London, E1 4NS, United Kingdom
[41]University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom
[42]University of Louisville, Louisville, Kentucky 40292, USA
[43]University of Manchester, Manchester M13 9PL, United Kingdom
[44]University of Maryland, College Park, Maryland 20742, USA
[45]University of Massachusetts, Amherst, Massachusetts 01003, USA
[46]Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Massachusetts 02139, USA
[47]McGill University, Montréal, Québec, Canada H3A 2T8
[48]Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy
[49]University of Mississippi, University, Mississippi 38677, USA
[50]Université de Montréal, Physique des Particules, Montréal, Québec, Canada H3C 3J7
[51]Mount Holyoke College, South Hadley, Massachusetts 01075, USA
[52]Università di Napoli Federico II, Dipartimento di Scienze Fisiche and INFN, I-80126, Napoli, Italy
[53]NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands
[54]University of Notre Dame, Notre Dame, Indiana 46556, USA
[55]Ohio State University, Columbus, Ohio 43210, USA
[56]University of Oregon, Eugene, Oregon 97403, USA
[57]Università di Padova, Dipartimento di Fisica and INFN, I-35131 Padova, Italy
[58]Universités Paris VI et VII, Laboratoire de Physique Nucléaire et de Hautes Energies, F-75252 Paris, France
[59]University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
[60]Università di Perugia, Dipartimento di Fisica and INFN, I-06100 Perugia, Italy
[61]Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy
[62]Prairie View A&M University, Prairie View, Texas 77446, USA
[63]Princeton University, Princeton, New Jersey 08544, USA
[64]Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy
[65]Universität Rostock, D-18051 Rostock, Germany
[66]Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom
[67]DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France
[68]University of South Carolina, Columbia, South Carolina 29208, USA
[69]Stanford Linear Accelerator Center, Stanford, California 94309, USA
[70]Stanford University, Stanford, California 94305-4060, USA
[71]State University of New York, Albany, New York 12222, USA
[72]University of Tennessee, Knoxville, Tennessee 37996, USA
[73]University of Texas at Austin, Austin, Texas 78712, USA
[74]University of Texas at Dallas, Richardson, Texas 75083, USA
[75]Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy
[76]Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy
[77]IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain
[78]University of Victoria, Victoria, British Columbia, Canada V8W 3P6
[79]Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom

[80] University of Wisconsin, Madison, Wisconsin 53706, USA
[81] Yale University, New Haven, Connecticut 06511, USA

(Dated: February 7, 2008)

We report searches for B-meson decays to the charmless final states ρK^* and $f_0(980)K^*$ with a sample of 232 million $B\overline{B}$ pairs collected with the *BABAR* detector at the PEP-II asymmetric-energy e^+e^- collider at SLAC. We measure the following branching fractions in units of 10^{-6}: $\mathcal{B}(B^+ \to \rho^0 K^{*+}) = 3.6 \pm 1.7 \pm 0.8\ (< 6.1)$, $\mathcal{B}(B^+ \to \rho^+ K^{*0}) = 9.6 \pm 1.7 \pm 1.5$, $\mathcal{B}(B^0 \to \rho^- K^{*+}) = 5.4 \pm 3.6 \pm 1.6\ (< 12.0)$, $\mathcal{B}(B^0 \to \rho^0 K^{*0}) = 5.6 \pm 0.9 \pm 1.3$, $\mathcal{B}(B^+ \to f_0(980)K^{*+}) = 5.2 \pm 1.2 \pm 0.5$, and $\mathcal{B}(B^0 \to f_0(980)K^{*0}) = 2.6 \pm 0.6 \pm 0.9\ (< 4.3)$. The first error quoted is statistical, the second systematic, and the upper limits, in parentheses, are given at the 90% confidence level. For the statistically significant modes we also measure the fraction of longitudinal polarization and the charge asymmetry: $f_L(B^+ \to \rho^+ K^{*0}) = 0.52 \pm 0.10 \pm 0.04$, $f_L(B^0 \to \rho^0 K^{*0}) = 0.57 \pm 0.09 \pm 0.08$, $\mathcal{A}_{\rm CP}(B^+ \to \rho^+ K^{*0}) = -0.01 \pm 0.16 \pm 0.02$, $\mathcal{A}_{\rm CP}(B^0 \to \rho^0 K^{*0}) = 0.09 \pm 0.19 \pm 0.02$, $\mathcal{A}_{\rm CP}(B^+ \to f_0(980)K^{*+}) = -0.34 \pm 0.21 \pm 0.03$, and $\mathcal{A}_{\rm CP}(B^0 \to f_0(980)K^{*0}) = -0.17 \pm 0.28 \pm 0.02$.

PACS numbers: 13.25.Hw, 11.30.Er, 12.15.Hh

The study of B-meson decays to charmless hadronic final states plays an important role in understanding CP violation. The charmless decays $B \to \rho K^*$ proceed through dominant penguin loops and Cabibbo-suppressed tree processes ($B^+ \to \rho^+ K^{*0}$ is pure penguin) to two vector particles (VV). A large longitudinal polarization fraction f_L (of order $(1 - 4m_V^2/m_B^2) \sim 0.9$) is predicted for both tree and penguin dominated VV decays [1]. However, recent measurements of the pure penguin VV decays $B \to \phi K^*$ indicate $f_L \sim 0.5$ [2]. Several attempts to understand this small value of f_L within or beyond the Standard Model (SM) have been made [3]. Further information about $SU(3)$-related decays may provide some insight into this polarization puzzle. Characterization of the four $B \to \rho K^*$ modes can also be used within the SM framework to help constrain the angles α and γ of the Unitarity Triangle [4].

We report measurements of branching fractions, longitudinal polarizations, and direct CP-violating asymmetries for the $B \to \rho K^*$ decay modes. We also measure branching fractions and direct CP-violating asymmetries for the $B \to f_0(980)K^*$ modes that share the same final states. We present improved analyses of previously measured modes [5], with larger statistics and explicit consideration of non-resonant backgrounds. We measure $B^0 \to \rho^- K^{*+}$, $B^0 \to \rho^0 K^{*0}$, $B^+ \to f_0(980)K^{*+}$, and $B^0 \to f_0(980)K^{*0}$ for the first time. Charge-conjugate modes are implied throughout.

This analysis is based on a data sample of 232 million $B\overline{B}$ pairs, corresponding to an integrated luminosity of 210 fb^{-1}, collected with the *BABAR* detector [6] at the SLAC PEP-II asymmetric-energy e^+e^- collider operating at a center-of-mass (c.m.) energy $\sqrt{s} = 10.58\,\mathrm{GeV}$, corresponding to the $\Upsilon(4S)$ resonance mass.

The angular distribution of the ρK^* decay products, after integrating over the angle between the decay planes of the vector mesons, for which the acceptance is uniform, is proportional to

$$\frac{1}{4}(1 - f_L)\sin^2\theta_{K^*}\sin^2\theta_\rho + f_L\cos^2\theta_{K^*}\cos^2\theta_\rho, \qquad (1)$$

where θ_{K^*} and θ_ρ are the helicity angles of the K^* and ρ, defined between the $K(\pi^+)$ momentum and the direction opposite to the B in the $K^*(\rho)$ rest frame [7]. We also measure the time-integrated direct CP-violating asymmetry $\mathcal{A}_{\rm CP} = (\Gamma^- - \Gamma^+)/(\Gamma^- + \Gamma^+)$, where the superscript on the total width Γ indicates the sign of the b-quark charge in the B meson.

We fully reconstruct charged and neutral decay products including the intermediate states ρ^0 or $f_0(980) \to \pi^+\pi^-$, $\rho^+ \to \pi^+\pi^0$, $K^{*0} \to K^+\pi^-$, $K^{*+} \to K^+\pi^0$, $K^{*+} \to K^0_S\pi^+$ (only in $\rho^0 K^{*+}$), $\pi^0 \to \gamma\gamma$, and $K^0_S \to \pi^+\pi^-$. We assume the $f_0(980)$ measured lineshape [8] and a branching ratio of 100% for $f_0(980) \to \pi^+\pi^-$. Table I lists the selection requirements on the invariant mass and helicity angle of B-daughter resonances.

TABLE I: Selection requirements on the invariant mass (in GeV) and helicity angle of B-daughter resonances.

Mode	$m_{\pi\pi}$	$m_{K\pi}$	$\cos\theta_\rho$	$\cos\theta_{K^*}$
$\rho^0 K^{*+}_{K^+\pi^0}$	(0.52,1.10)	(0.75,1.05)	(-0.95,0.95)	(-0.5,1.0)
$\rho^0 K^{*+}_{K^0_S\pi^+}$	(0.52,1.10)	(0.75,1.05)	(-0.95,0.95)	(-0.9,1.0)
$\rho^+ K^{*0}$	(0.40,1.15)	(0.77,1.02)	(-0.66,0.95)	(-0.95,1.0)
$\rho^- K^{*+}_{K^+\pi^0}$	(0.40,1.15)	(0.77,1.02)	(-0.80,0.98)	(-0.80,0.98)
$\rho^0 K^{*0}$	(0.52,1.15)	(0.77,1.02)	(-0.95,0.95)	(-0.95,1.0)

Charged tracks from the B-meson candidate are required to originate from the interaction point. Looser criteria are applied to tracks forming K^0_S candidates, for which we require $|m_{\pi^+\pi^-} - m_{K^0_S}| < 12\,\mathrm{MeV}$, a measured proper decay time greater than five times its uncertainty, and the cosine of the angle between the reconstructed flight and momentum directions to exceed 0.995. Charged particle identification provides discrimination between kaons and pions, and is also used to reject electrons and protons. We reconstruct π^0 mesons from pairs of photons, each with a minimum energy of $30\,\mathrm{MeV}$ ($\rho^0 K^{*+}$) or $50\,\mathrm{MeV}$ ($\rho^+ K^{*0}$ and $\rho^- K^{*+}$). The invariant mass of π^0 candidates is required to be within $15\,\mathrm{MeV}$

($\rho^0 K^{*+}$) or 25 MeV ($\rho^+ K^{*0}$ and $\rho^- K^{*+}$) of the nominal mass [9].

B-meson candidates are characterized kinematically by the energy difference $\Delta E = E_B^* - \sqrt{s}/2$ and the energy-substituted mass $m_{\rm ES} = \left[(s/2 + \mathbf{p}_i \cdot \mathbf{p}_B)^2/E_i^2 - \mathbf{p}_B^2\right]^{1/2}$, where $(E_i, \mathbf{p}_i)$ and $(E_B, \mathbf{p}_B)$ are the four-momenta of the $\Upsilon(4S)$ and B candidate respectively, and the asterisk denotes the $\Upsilon(4S)$ frame. Our signal lies in the region $|\Delta E| \leq 0.1$ GeV and $5.27 \leq m_{\rm ES} \leq 5.29$ GeV. Sidebands in $m_{\rm ES}$ and ΔE are used to characterize the continuum background. The average number of signal B candidates per selected data event ranges from 1.05 to 1.27, depending on the final state. A single candidate per event is chosen as the one with the smallest B vertex-fit χ^2 ($\rho^+ K^{*0}$and $\rho^0 K^{*0}$), the smallest value of χ^2 constructed from deviations of reconstructed π^0 masses from the expected value ($\rho^- K^{*+}$), or randomly ($\rho^0 K^{*+}$). Monte Carlo (MC) simulation shows that up to 38% (23%) of longitudinally (transversely) polarized signal events are misreconstructed with one or more tracks originating from the other B in the event.

To reject the dominant $q\bar{q}$ continuum background we require $|\cos\theta_T| < 0.8$, where θ_T is the c.m. frame angle between the thrust axes of the B-candidate and that formed from the other tracks and neutral clusters in the event. We also use as discriminant variables the polar angles of the B-momentum vector and the B-candidate thrust axis with respect to the beam axis, and the two Legendre moments L_0 and L_2 of the energy flow around the B-candidate thrust axis in the c.m. frame [10]. These variables are combined in a Fisher discriminant $\mathcal{F}$ ($\rho^0 K^{*+}$) or a neural network (NN) (other modes). Finally, we suppress background from B decays to charmed states by removing signal candidates that have decay products consistent with $D^0 \to K^-\pi^+(\pi^0)$ and $D^- \to K^+\pi^-\pi^-$ decays.

We use an extended (not extended in the $\rho^+ K^{*0}$mode) unbinned maximum-likelihood (ML) fit to extract signal yields, asymmetries, and angular polarizations simultaneously. We define the likelihood $\mathcal{L}_i$ for each event candidate i as the sum of $n_j \mathcal{P}_j(\vec{x}_i; \vec{\alpha})$ over hypotheses j (signal, $q\bar{q}$ background, and several $B\overline{B}$ backgrounds discussed below), where the $\mathcal{P}_j(\vec{x}_i; \vec{\alpha})$ are the probability density functions (PDFs) for the measured variables $\vec{x}_i$, and n_j are the yields for the different hypotheses. The quantities $\vec{\alpha}$ represent parameters in the expected distributions of the measured variables for each hypothesis. They are extracted from MC simulation and $(m_{\rm ES}, \Delta E)$ sideband data. They are fixed in the fit except for some shape parameters of the continuum ΔE and $m_{\rm ES}$ distributions. The extended likelihood function for a sample of N candidates is $\mathcal{L} = \exp\left(-\sum n_j\right) \prod_{i=1}^N \mathcal{L}_i$.

The fit input variables $\vec{x}_i$ are $m_{\rm ES}$, ΔE, NN or $\mathcal{F}$, invariant masses of the candidates ρ ($f_0(980)$) and K^*, and helicity angles θ_ρ and θ_{K^*}. We study large control samples of $B \to D\pi$ decays of similar topology to verify the simulated resolutions in ΔE and $m_{\rm ES}$, adjusting the PDFs to account for any difference found.

Since almost all correlations among the fit input variables are found to be small, we take each $\mathcal{P}_j$ to be the product of the PDFs for the separate variables with the following exceptions where we explicitly account for correlations: the correlation between the two helicity angles in signal, the correlation due to misreconstructed events in signal, and the correlation between mass and helicity in backgrounds. The effect of neglecting other correlations is evaluated by fitting ensembles of simulated experiments in which we embed the expected numbers of signal and charmless B-background events, randomly extracted from fully-simulated MC samples.

We use MC-simulated events to study backgrounds from other B decays. Charmless B-backgrounds are grouped into up to 11 classes with similar topologies depending on the mode. Yields for decays with poorly known branching fractions are varied in the fit with those remaining kept fixed to their measured values. One to four additional classes account for neutral and charged B decays to final states with charm. Up to 6 classes account for misreconstructed events in signal. We also introduce components for non-resonant backgrounds such as $\pi\pi K^*$, $\rho K\pi$, $f_0(980)K\pi$, and $f_0(1370)K\pi$, which differ from signal only in resonance mass and helicity distributions. The magnitudes of these components are determined by extrapolating from fits performed on a wider mass range reaching to higher mass values and are fixed in the fit. Fig. 1 shows the sPlots [11] for the invariant mass of $K\pi$ and $\pi\pi$ in the $\rho^+ K^{*0}$and $\rho^0 K^{*0}$modes, respectively. The data events are weighted by their probability to be signal, calculated from the signal and backgrounds PDFs of the ΔE, $m_{\rm ES}$, and NN variables.

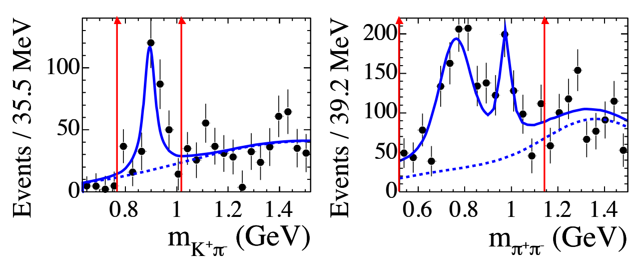

FIG. 1: sPlots for the invariant mass of $K\pi$ in $\rho^+ K^{*0}$(left) and $\pi\pi$ in $\rho^0 K^{*0}$and $f_0(980)K^{*0}$(right) up to the higher-mass regions. The points with error bars show the data, and the solid (dashed) lines show the projected PDFs of the signal and non-resonant background (non-resonant background only: $\rho K\pi$ in $\rho^+ K^{*0}$; the sum of $f_0(1370)K^*$, $\pi\pi K^*$, and $\pi\pi K\pi$ in $\rho^0 K^{*0}$). The arrows show the nominal fit regions.

The results of the ML fits are summarized in Table II. For the branching fractions, we assume equal production rates of B^+B^- and $B^0\overline{B}^0$. The significance S of a signal is defined by $\Delta\ln\mathcal{L} = S^2/2$, where $\Delta\ln\mathcal{L}$ represents the change in likelihood from the maximal value when the number of signal events is set to zero, corrected for the systematic error defined below. We find significant signals for ρ^+K^{*0}, ρ^0K^{*0}, and $f_0(980)K^{*+}$, and some evidence for $f_0(980)K^{*0}$. For the modes with significance smaller than five standard deviations we also measure the 90% confidence level (C.L.) upper limit, taking into account the systematic uncertainty. Fig. 2 shows projections of the fits onto $m_{\rm ES}$.

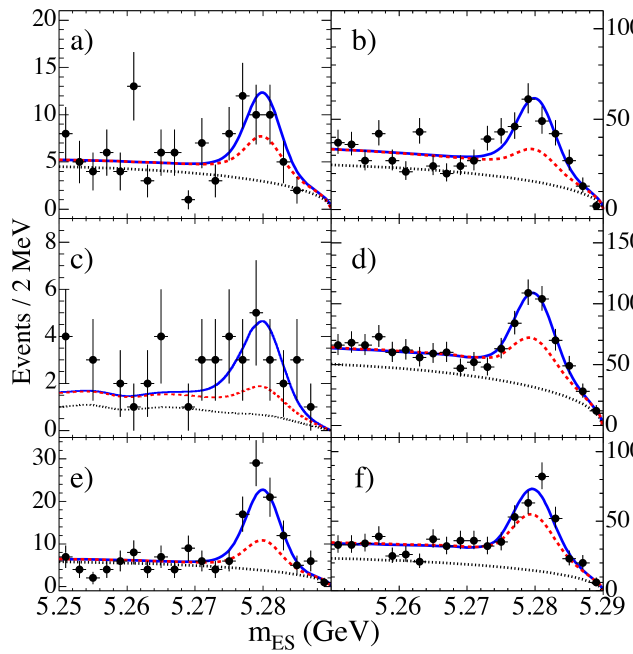

FIG. 2: Projections of the multidimensional fit onto $m_{\rm ES}$ for events passing a signal-to-total likelihood probability ratio cut with the plotted variable excluded for (a) ρ^0K^{*+}, (b) ρ^+K^{*0}, (c) ρ^-K^{*+}, (d) ρ^0K^{*0}, (e) $f_0(980)K^{*+}$, and (f) $f_0(980)K^{*0}$. The points with error bars show the data; the solid, dashed and dotted lines show the total, background, and continuum PDF projections respectively.

A source of systematic error is related to the determination of the PDFs and is due to the limited statistics of the Monte-Carlo and to the uncertainty on the PDF shapes. We obtain variations in the yields ranging from 1 to 18%, depending on the mode. The systematic error due to the non-resonant background extrapolation and interference with signal is in the range 6–21%. Event yields for B-background modes fixed in the fit are varied by their respective uncertainties. This results in a systematic uncertainty of 2–12%. We evaluate and correct for possible fit biases with MC experiments. We assign a systematic uncertainty of 1–7% for this.

The reconstruction efficiency depends on the decay polarization. For the ρ^0K^{*+}mode we calculate the efficiency using the measured polarization (combined for the two ρ^0K^{*+}modes) and assign a systematic uncertainty corresponding to the total polarization measurement error (9 and 20% for each mode respectively). For the other modes we exploit the correlation between $\mathcal{B}$ and f_L and obtain the values of $\mathcal{B}$ from fits where $\mathcal{B}$ and f_L are free parameters. Fig. 3 shows the behavior of $-2\ln\mathcal{L}(f_L,\mathcal{B})$ for the modes with significant signal.

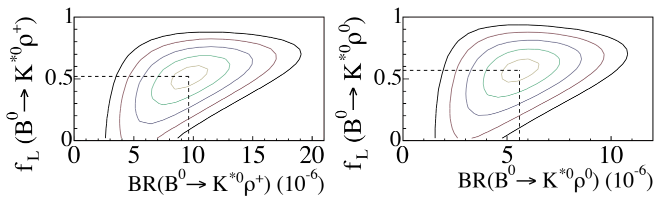

FIG. 3: Distribution of $-2\ln\mathcal{L}(\mathcal{B},f_L)$ for $B^+\to\rho^+K^{*0}$(left) and $B^0\to\rho^0K^{*0}$(right) decays. The solid dots correspond to the central values and the curves give contours in $\Delta\sqrt{-2\ln\mathcal{L}(\mathcal{B},f_L)}=1$ steps.

Additional reconstruction efficiency uncertainties arise from tracking (3–5%), particle identification (1–2%), vertex probability (2%), track multiplicity (1%) and thrust angle (1%). K^0_S and π^0 reconstruction contribute 2.3% and 3% uncertainty, respectively. Other minor systematic effects are from uncertainty in daughter branching fractions, MC samples statistics, and number of B mesons. The absolute systematic uncertainty in f_L takes into account PDF shape variations (5–10%), B and non-resonant backgrounds (4–8%), and efficiency dependence on the polarization (1–2%). The absolute uncertainty in the charge asymmetry due to track charge bias is less than 1%. PDF variations and fixed B-background effects contribute up to 2%.

In summary, we have searched for $B\to\rho K^*$ and $B\to f_0(980)K^*$ decays. We observe $B^+\to\rho^+K^{*0}$, $B^0\to\rho^0K^{*0}$, $B^+\to f_0(980)K^{*+}$, and $B^0\to f_0(980)K^{*0}$ with 7.1, 5.3, 5.0, and 3.5 σ significance respectively. We measure the branching fractions or 90% C.L. upper limits, the fractions of longitudinal polarization, and the charge asymmetries, summarized in Table II. The measured polarization in the ρ^+K^{*0} and ρ^0K^{*0} modes agrees with values measured in ϕK^* decays.

We thank I. Bigi, S. Descotes-Genon, O. Pène, and M. Pennington for their advice on the treatment of non-resonant backgrounds. We are grateful for the excellent luminosity and machine conditions provided by our PEP-II colleagues, and for the substantial dedicated effort from the computing organizations that support *BABAR*. The collaborating institutions wish to thank SLAC for its support and kind hospitality. This work is supported by DOE and NSF (USA), NSERC (Canada), IHEP (China), CEA and CNRS-IN2P3 (France), BMBF and DFG (Germany), INFN (Italy), FOM (The Netherlands), NFR (Norway), MIST (Russia), MEC (Spain), and PPARC (United Kingdom). Individuals have received support from the Marie Curie EIF (European Union) and the A. P. Sloan Foundation.

TABLE II: Summary of results for the measured B-decay modes: signal yield n_{sig} and its statistical uncertainty, reconstruction efficiency ε, daughter branching fraction product $\prod \mathcal{B}_i$, significance S (systematic uncertainties included), measured branching fraction $\mathcal{B}$, (90% C.L. upper limit in parentheses), measured longitudinal polarization f_L (for the modes with non-significant signals the numbers, in brackets, are not quoted as measurements) and charge asymmetry $\mathcal{A}_{\rm CP}$.

Mode	n_{sig}	$\varepsilon(\%)$	$\prod \mathcal{B}_i(\%)$	$S(\sigma)$	$\mathcal{B}(10^{-6})$	f_L	$\mathcal{A}_{\rm CP}$
$\rho^0 K^{*+}$				2.5	$3.6^{+1.7}_{-1.6} \pm 0.8$ (6.1)	$[0.9 \pm 0.2]$	–
$\rightarrow\rho^0 K^{*+}_{K^+\pi^0}$	19^{+16}_{-15}	7.9	32.9	1.3	$3.2^{+2.7}_{-2.4} \pm 0.9$	$[0.8^{+0.3}_{-0.5}]$	–
$\rightarrow\rho^0 K^{*+}_{K^0_S\pi^+}$	32^{+19}_{-17}	15.8	22.9	2.1	$3.8^{+2.2}_{-2.1} \pm 0.9$	$[1.0 \pm 0.3]$	–
$\rho^+ K^{*0}$	194 ± 29	13.5	66.7	7.1	$9.6 \pm 1.7 \pm 1.5$	$0.52 \pm 0.10 \pm 0.04$	$-0.01 \pm 0.16 \pm 0.02$
$\rho^- K^{*+}_{K^+\pi^0}$	60^{+25}_{-22}	15.2	32.5	1.6	$5.4^{+3.8}_{-3.4} \pm 1.6$ (12.0)	$[-0.18^{+0.52}_{-1.74}]$	–
$\rho^0 K^{*0}$	185 ± 30	22.9	66.7	5.3	$5.6 \pm 0.9 \pm 1.3$	$0.57 \pm 0.09 \pm 0.08$	$0.09 \pm 0.19 \pm 0.02$
$f_0(980)K^{*+}$				5.0	$5.2 \pm 1.2 \pm 0.5$	–	$-0.34 \pm 0.21 \pm 0.03$
$\rightarrow f_0(980)K^{*+}_{K^+\pi^0}$	40^{+13}_{-12}	8.5	32.9	3.8	$6.2^{+2.1}_{-1.9} \pm 0.7$	–	$-0.50 \pm 0.29 \pm 0.03$
$\rightarrow f_0(980)K^{*+}_{K^0_S\pi^+}$	37^{+14}_{-12}	16.6	22.9	3.2	$4.2^{+1.5}_{-1.4} \pm 0.5$	–	$-0.13 \pm 0.30 \pm 0.01$
$f_0(980)K^{*0}$	83 ± 19	21.7	66.7	3.5	$2.6 \pm 0.6 \pm 0.9$ (4.3)	–	$-0.17 \pm 0.28 \pm 0.02$

* Also at Laboratoire de Physique Corpusculaire, Clermont-Ferrand, France
† Also with Università di Perugia, Dipartimento di Fisica, Perugia, Italy
‡ Also with Università della Basilicata, Potenza, Italy

[1] A. Ali *et al.*, Z. Phys. C **1**, 269 (1979); M. Suzuki, Phys. Rev. D **66**, 054018 (2002).
[2] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **93**, 231804 (2004); Belle Collaboration, K.-F. Chen *et al.*, Phys. Rev. Lett. **94**, 221804 (2005).
[3] A. Kagan, Phys. Lett. B **601**, 151 (2004); C. Bauer *et al.*, Phys. Rev. D **70**, 054015 (2004); P. Colangelo *et al.*, Phys. Lett. B **597**, 291 (2004); M. Ladisa *et al.*, Phys. Rev. D **70**, 114025 (2004); H.n. Li and S. Mishima, Phys. Rev. D **71**, 054025 (2005); M. Beneke *et al.*, Phys. Rev. Lett. **96**, 141801 (2006).
[4] D. Atwood and A. Soni, Phys. Rev. D **65**, 073018 (2002); M. Beneke *et al.*, hep-ph/0604005, submitted to Phys. Lett. B.
[5] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **91**, 171802 (2003); Belle Collaboration, J. Zhang *et al.*, Phys. Rev. Lett. **95**, 141801 (2005); CLEO Collaboration, R. Godang *et al.*, Phys. Rev. Lett. **88**, 021802 (2002).
[6] *BABAR* Collaboration, B. Aubert *et al.*, Nucl. Instrum. Methods Phys. Res., Sect A **479**, 1 (2002).
[7] G. Kramer and W.F. Palmer, Phys. Rev. D **45**, 193 (1992).
[8] E.M. Aitala *et al.*, Phys. Rev. Lett. **86**, 765 (2001).
[9] W.-M. Yao *et al.*, J. Phys. G **33**, 1 (2006).
[10] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **70**, 032006 (2004).
[11] M. Pvik and F. Le Diberder, Nucl. Instrum. Methods Phys. Res., Sect A **555**, 356 (2005).

Measurements of branching fractions, polarizations, and direct CP-violation asymmetries in $B \to \rho K^*$ and $B \to f_0(980)K^*$ decays

We report searches for B-meson decays to the charmless final states ρK^* and $f_0(980)K^*$ with a sample of 232 million $B\overline{B}$ pairs collected with the *BABAR* detector at the PEP-II asymmetric-energy e^+e^- collider at SLAC. We measure the following branching fractions in units of 10^{-6}: $\mathcal{B}(B^+ \to \rho^0 K^{*+}) = 3.6 \pm 1.7 \pm 0.8$ (< 6.1), $\mathcal{B}(B^+ \to \rho^+ K^{*0}) = 9.6 \pm 1.7 \pm 1.5$, $\mathcal{B}(B^0 \to \rho^- K^{*+}) = 5.4 \pm 3.6 \pm 1.6$ (< 12.0), $\mathcal{B}(B^0 \to \rho^0 K^{*0}) = 5.6 \pm 0.9 \pm 1.3$, $\mathcal{B}(B^+ \to f_0(980) K^{*+}) = 5.2 \pm 1.2 \pm 0.5$, and $\mathcal{B}(B^0 \to f_0(980) K^{*0}) = 2.6 \pm 0.6 \pm 0.9$ (< 4.3). The first error quoted is statistical, the second systematic, and the upper limits, in parentheses, are given at the 90% confidence level. For the statistically significant modes we also measure the fraction of longitudinal polarization and the charge asymmetry: $f_L(B^+ \to \rho^+ K^{*0}) = 0.52 \pm 0.10 \pm 0.04$, $f_L(B^0 \to \rho^0 K^{*0}) = 0.57 \pm 0.09 \pm 0.08$, $\mathcal{A}_{\rm CP}(B^+ \to \rho^+ K^{*0}) = -0.01 \pm 0.16 \pm 0.02$, $\mathcal{A}_{\rm CP}(B^0 \to \rho^0 K^{*0}) = 0.09 \pm 0.19 \pm 0.02$, $\mathcal{A}_{\rm CP}(B^+ \to f_0(980) K^{*+}) = -0.34 \pm 0.21 \pm 0.03$, and $\mathcal{A}_{\rm CP}(B^0 \to f_0(980) K^{*0}) = -0.17 \pm 0.28 \pm 0.02$.